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14. ABSTRACT
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Report Title

The effect of social contexts on network response to emergencies

ABSTRACT

We study how social communication behaviors change when the population encounters unfamiliar conditions, which has potential to provide insights into improving resource management in response to emergencies and crises, as well as to o er new perspective on information propagation. Using anonymous billing records of 10 million mobile phone subscribers in a western European country from 2007 to 2009, we compare call activity in the immediate aftermath of a set of emergencies with scheduled events (such as rock concerts and sporting events). We ?nd that, despite the communication avalanches accompanying large-scale emergencies due to the signi?cant population of eyewitnesses, the calling targets of these calls are more predictable than those in normal situations. We use predictive models to discover key factors related to people's calling decisions and show that people's calling behaviors in emergencies di er from those in normal situations (scheduled events or non-event periods). The ?nding suggests people's e ective social networks change with different situations. Comparing with their social networks in normal period, people's strong ties are reasserted during emergencies, but may adjusted by other context-dependent factors such as geographical distance. In contrast, the networks are more likely to be reshu□ed by scheduled activities.

The effect of social contexts on network response to emergencies

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We study how social communication behaviors change when the population encounters unfamiliar conditions, which has potential to provide insights into improving resource management in response to emergencies and crises, as well as to offer new perspective on information propagation. Using anonymous billing records of 10 million mobile phone subscribers in a western European country from 2007 to 2009, we compare call activity in the immediate aftermath of a set of emergencies with scheduled events (such as rock concerts and sporting events). We find that, despite the communication avalanches accompanying large-scale emergencies due to the significant population of eyewitnesses, the calling targets of these calls are more predictable than those in normal situations. We use predictive models to discover key factors related to people's calling decisions and show that people's calling behaviors in emergencies differ from those in normal situations (scheduled events or non-event periods). The finding suggests people's effective social networks change with different situation. Comparing with their social networks in normal period, people's strong ties are reasserted during emergencies, but may adjusted by other context-dependent factors such as geographical distance. In contrast, the networks are more likely to be reshuffled by scheduled activities.

A critical resource for many organizations are the behavioral data that they have about individuals, especially regarding their networks. It has become increasingly clear that within organizations, knowledge sharing, innovation, and the like are critically determined by ties to others within the organization. Similarly, outside of organizations, identifying opinion leaders, where behaviors might spread (or not spread) are also powerfully related by social relationships. What is less clear is how to identify critical relationships from the cacophony of information from various sources – how to find important relationships among the many unimportant relationships? Here we propose a general approach, a natural experiment of a sort, where an exogenous event occurs which (we assert) should lead individuals to communicate with certain types of ties. Those events are emergencies of various types (earthquakes, bombings, etc), and the data are mobile phone data from the individuals located on the scene. What are the behavioral correlates (based on prior observed) of who individuals call in an emergency? How does this vary with demographic factors, and how does it deviate from the "average" behavior of individuals?

Recent studies have shown intriguing characteristics on human dynamics and interactions, such as high predictability in mobility [1], communication activity [2], and coupling between structure and tie strengths [3]. The recent availability of new cutting edge datasets such as cell phone call records [3] offers unprecedented opportunities to study the large scale social communications and human dynamics. However, most research has focused on characterizing the regular daily activity of individuals [4, 3, 1, 2], while there is exceptional need to understand how people change their behavior when exposing to unfamiliar conditions, such as natural disasters, emergencies and traffic anomalies [5]. Such understanding will help provide insights into transforming the ways of personnel and machinery responding to potential tragedies, as well as help redefine our understanding of information propagation.

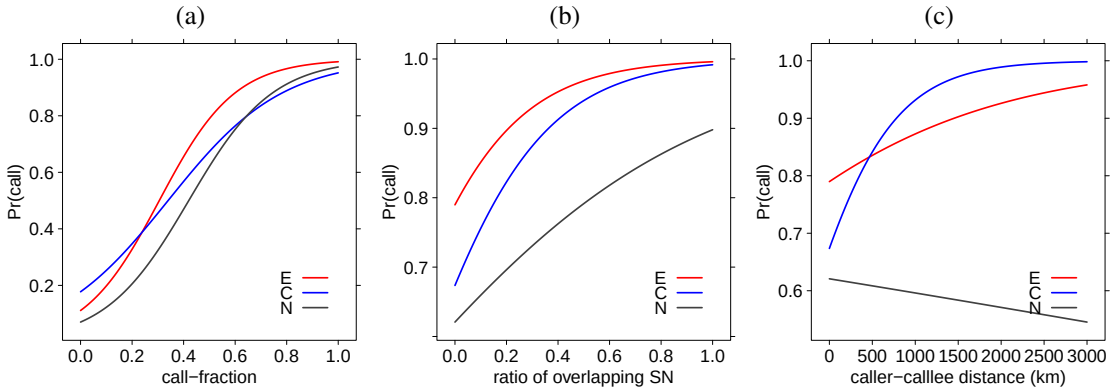


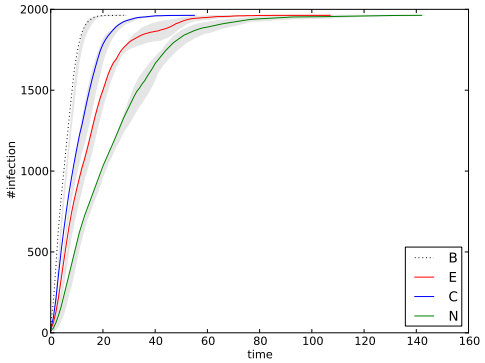
Figure 1: Effect of call-fraction, ratio of shared contacts, and caller-callee distance. **(a)** In emergencies (denoted as "E"), call-fraction increases the calling odds by a factor of 6.8, significantly higher than scheduled events (denoted as "C") and non-event period (denoted as "N"). **(b)** During emergencies, people are more likely to call the those who share more social contacts with them. **(c)** During emergencies, people tend to call the those who are distant from them.

In this work we study how social communication behaviors change along the links of underlying social network, when the population encounters unfamiliar conditions. Using anonymous billing records of 10 million mobile phone subscribers in a western European country from 2007 to 2009, we identify 11 events about societal and natural emergencies, ranging from bombings, a plane crash, earthquakes to storms. To distinguish emergencies from another possible cause of human activity change, we also study 12 planned activities as "control events," including rock concerts and sporting events. We seek to capture patterns in both situations to contrast with normal periods, referenced as "null events," where no significant calling anomalies can be detected.

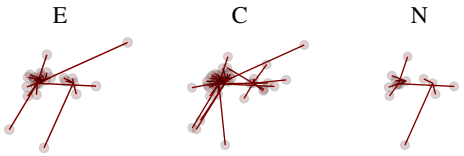
How do people's calling behaviors change during emergencies? What are the key factors that dominate people's calling decisions, specifically, the calling targets, in emergencies? To characterize the changes in communication behaviors, we track both user mobility and communications of the affected population of individual events (including emergencies, control and null events), over 12 weeks until the events happened. We use these prior-event records as training corpus and utilize predictive models (generalized linear models) to discover key factors related to people's decisions about calling targets during the events. The effectiveness of our models has been evaluated through a leave-one-event-out cross-validation, with over 80% accuracy on average.

We have found that the factors that effectively predict people's calling behaviors in emergencies differ from those in normal situations, and social context factors are crucial in predicting calling targets in emergencies. In summary, our results show that (Fig. 1), during emergencies, people are more likely to call those who they normally call more frequently, who share more contacts, and who are distant from their likely locations. Comparing with their social networks in normal period, people's strong ties are reasserted during emergencies, but may adjusted by other context-dependent factors such as geographical distance.

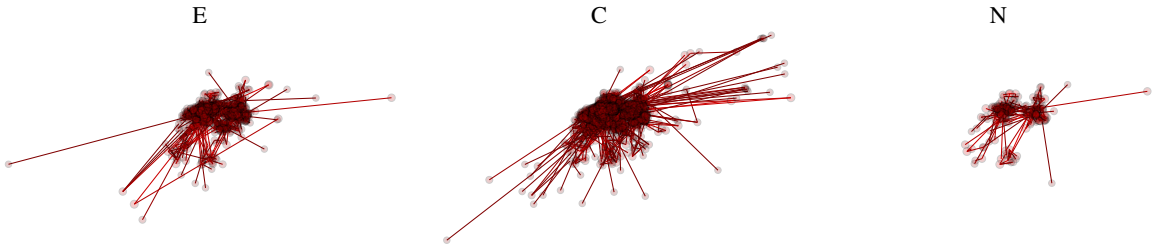
To further examine the impact of the changing behaviors during emergencies, we conduct a simulation of information spreading on 10 networks sampled from the phone data, with network size ranging from thousands to millions. The simulation is based on the susceptible-infected model of epidemiology and the normalized spreading probability on each link is given by the predictive models trained from three different situations. As shown in Fig. 2a, the information propagation during emergencies is significantly faster than



(a) information spreading rate



(b) spreading at $t = 1$



(c) spreading at $t = 5$

Figure 2: The impact of change in communication behavior during events. **(a)** The information spreading in emergencies (E) is significantly higher than that in null events (N), but slower in control events (C). All three situations are compared with the baseline network (B) where all calling probabilities are considered equal. **(b)** An instantiation of information spreading on a network over three situations at the end of the first timestep. The nodes represent individuals with positions covey their geographical locations of making a call. **(c)** The spreading of the same network at the end of the 5^{th} timestep. The example illustrates that information spreading in control events are more likely to escape the geographic boundaries than in emergencies. The simulation suggest information spreading depends on people's effective social networks which change with different situation, where context-dependent factors such as geographical distance are more likely to dominate the calling decisions.

that in null events, but slower in control events. Figure 2 (b) and (c) illustrate the process of information spreading on a sampled network, where nodes represent individuals with positions covey their geographical locations of making a call. We see information is more likely to escape the geographic boundaries in control and emergency events.

The current finding suggests people's effective social networks change with different situations. During emergencies, the reinforcement of strong ties and other context-dependent factors such as geographical distance has dominated people's calling decision, while in scheduled events the communication networks are more likely to mutate from people's "average" networks developed over time.

Our study also suggests that it is possible to predict a large-scale network dynamics, such as information propagation, by transforming the set of micro-level network components–individuals' present multiplex ties interacting with context factors–at similar conditions. Further work includes quantifying the effects of age and gender on calling prediction, and understanding how calling decision correlates with social network with geographical constraints.

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